Basin-scale Ocean Prediction with the Hybrid Coordinate Ocean Model

Eric P. Chassignet, Patrick J. Hogan, Harley E. Hurlburt,
E. Joseph Metzger, and Alan J. Wallcraft

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MAIN OBJECTIVE:

- **To perform a realistic, truly eddy resolving, wind- and buoyancy-forced numerical simulation of the global ocean with sophisticated data assimilation techniques that can be efficiently executed on massively parallel computers**

- **To assess its nowcast/forecast capabilities for both Lagrangian trajectories and 3-D Eulerian fields such as velocity, temperature, salinity, and density**

THREE MAJOR COMPONENTS:

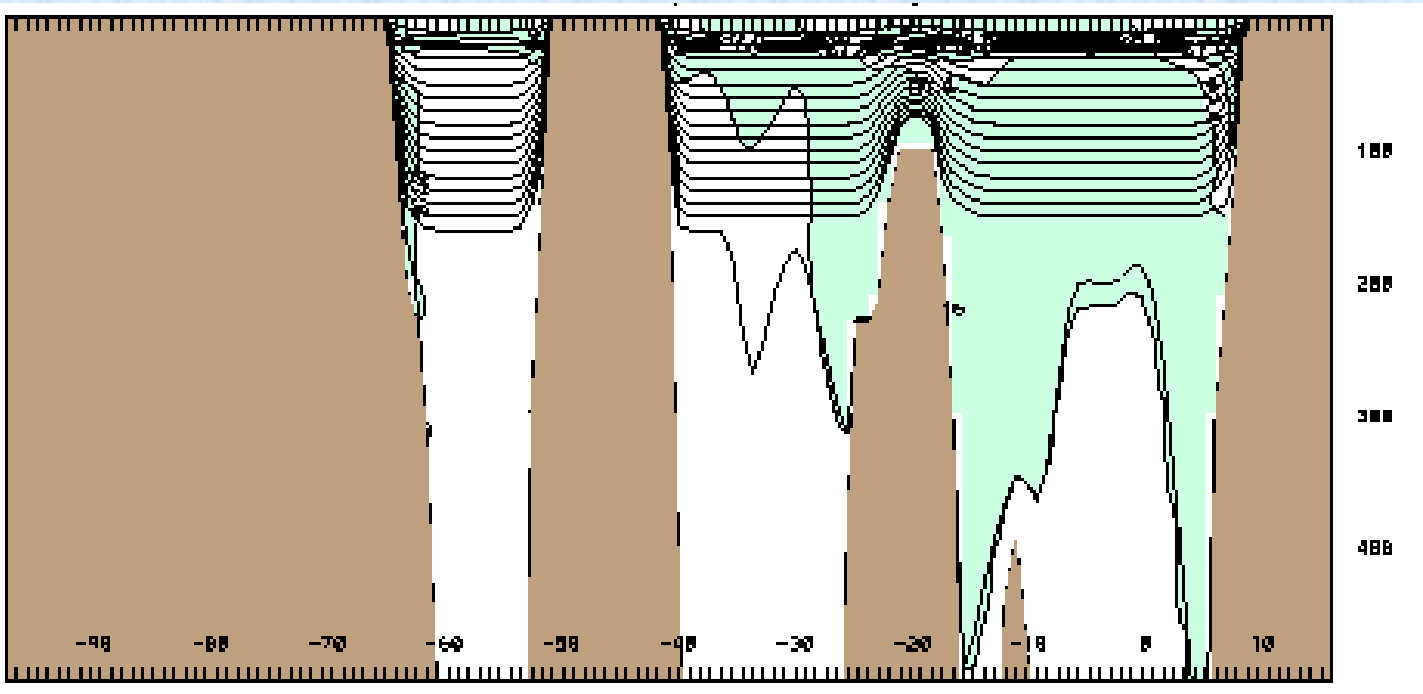
1. **The ocean model: the HYbrid Coordinate Ocean Model (HYCOM)**

2. **Data from satellite-derived sea surface height and temperature fields**

3. **Data assimilation techniques**

HYCOM

The hybrid coordinate is one that is isopycnal in the open, stratified ocean, but smoothly reverts to a terrain-following coordinate in shallow coastal regions, and to pressure coordinates in the mixed layer and/or unstratified seas.



Status of HYCOM

- HYCOM 2.0 (released 3 July 2001)
  - Scalability via MPI and or OpenMP (2-1000 cpus)
  - FORTRAN 90 coding style
  - Single source code, for all machine types
  - Bit for bit multi-cpu reproducibilty
- Nesting
  - Off-line and one-way
  - Based on enclosing regions archive files
- MICOM compatibility
  - MICOM-like mode
  - Can continue a true MICOM simulation
  - Convert MICOM-like to HYCOM-mode
  - Add/subtract layers

HYCOM Long Term Goals for Operational Ocean Prediction

- **.08° fully-global ocean prediction system transitioned to NAVO in 2006**
  - ~ 7 km mid-latitude resolution
  - Include shallow water, minimum depth 10 m
  - Bi-Polar (PanAm) grid for Arctic
  - Embedded ice model

- **Increase to .04° resolution globally and transition to NAVO by the end of the decade**
  - ~3.5 km mid-latitude resolution
  - Good resolution for coastal model boundary conditions globally
  - "Baseline" resolution for shelf regions globally

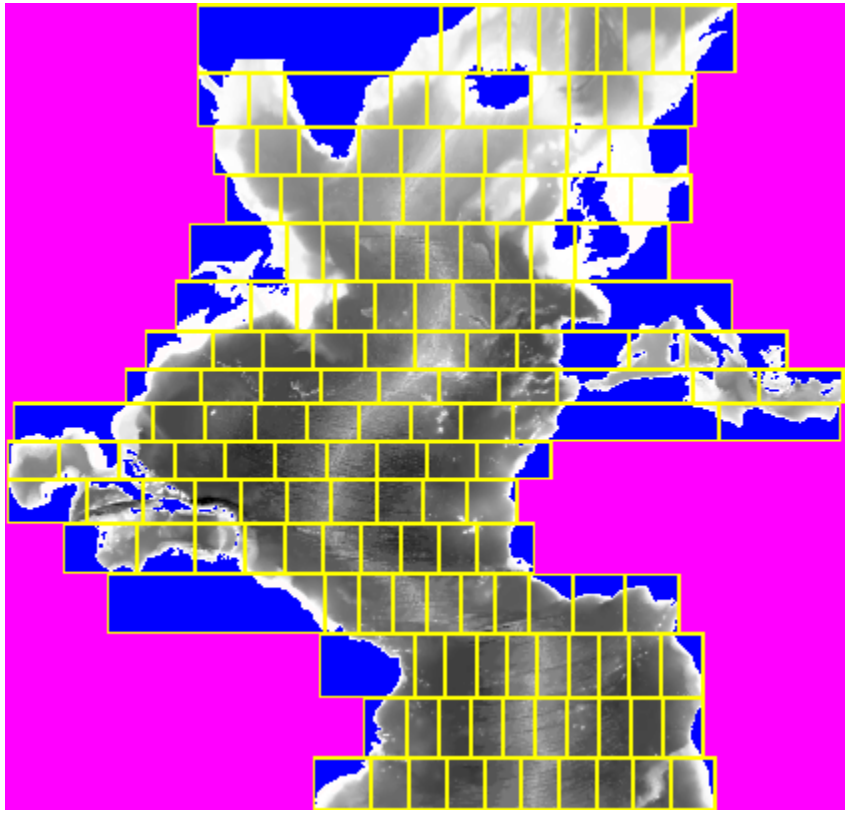
- **A cost-effective methodology for ocean model transition**
  - Perform basin scale prior to global
  - Evaluate assimiliation techniques in one basin
  - Need ~5 year lead-time prior to transition to operational status

Atlantic Model Configuration

- Horizontal grid: 1/12˚ (1678 x 1609 grid points, 6.5 km spacing on average)
- 28°S to 70˚N (including the Mediterranean Sea)
- 26 vertical coordinate surfaces (σ-theta reference)
- Bathymetry: Quality controlled ETOPO5
- Surface forcing: wind stress, wind speed, heat flux (using bulk formula) E-P + relaxation to cllimatological surface salinity
- River runoff included
- Buffer zone: ~3°band along the northern and southern boundaries with relaxation to monthly climatological T and S (Levitus)

1/12° North Atlantic Grand Challenge Project

10 x 16 Equal Ocean Decomposition



- Running on brainerd (ARL)
- 58,000 CPU hrs/model year on 160 CPUs
- 770 GB/model year for daily 3-D output
- MPI parallelization

HYCOM 1/12° North Atlantic Simulations

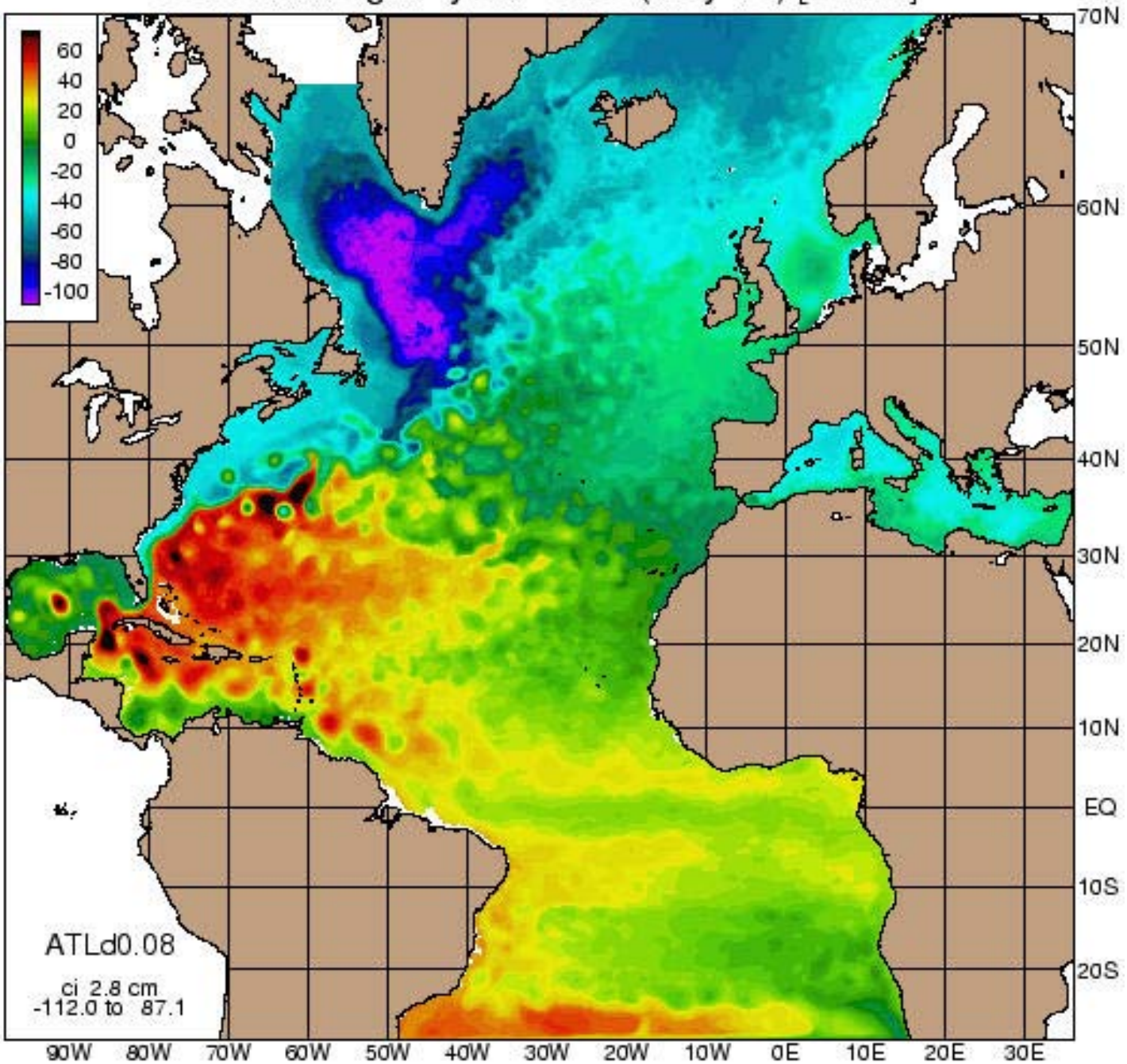
- Restarted from a 20-layer MICOM simulation
  (run under a previous Grand Challenge project)

- 5 layers added near surface for increased vertical resolution
  In the mixed layer

- Ran 1.5 years with monthly ECMWF surface forcing

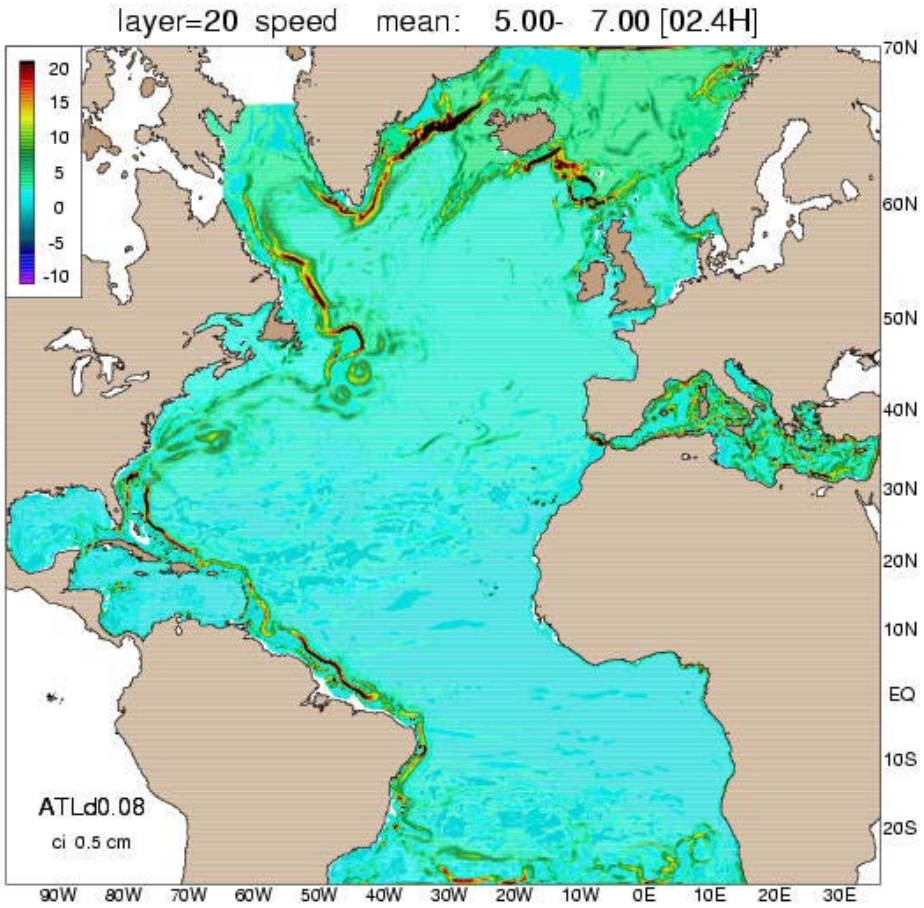
- Continued for 2.5 years with a high frequency wind component for more realistic mixed layer depths

- Continued with mean ECMWF forcing with 6 hourly NOGAPS operational wind and flux forcing July 1999-December 2001 (currently in May 2000)
  - ➢Baseline run for data assimilative simulation


sea surf. height year 7.38 (may 18) [02.5H]
60
40
20
0
-20
-40
-60
-80
-100
70N
60N
50N
40N
30N
20N
10N
EQ
10S
20S
90W
80W
70W
60W
50W
40W
30W
20W
10W
0E
10E
20E
30E
ATLd0.08
ci 2.8 cm
-112.0 to 87.1

1/12° Atlantic HYCOM

Deep Western Boundary Current

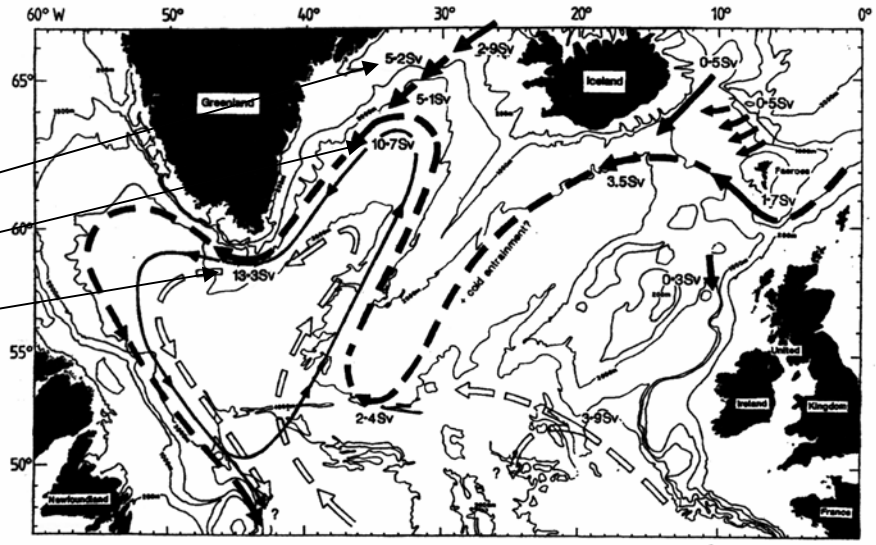


Forced with ECMWF climatological winds and fluxes and relaxation to Levitus at the north/south boundary

Denmark Straits Overflow Region

Volume transport
from current meters

5.2
10.7
13.3

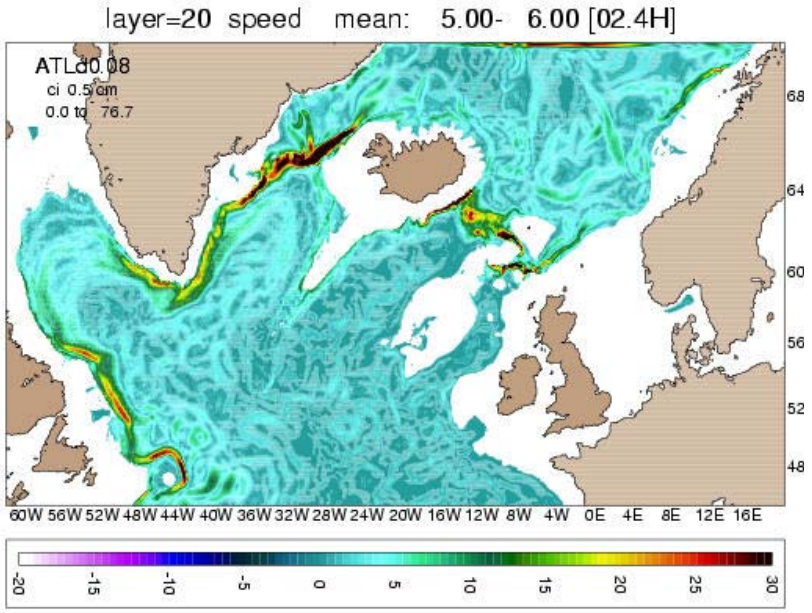


Dickson and Brown
1994 (JGR)

Figure 13. Proposed transport scheme for waters denser than $\sigma\theta = 27.80$ in the northern North Atlantic, based on all available measurements.

Volume transport
sum Layers 20-26
ρ > 27.8 (NADW)

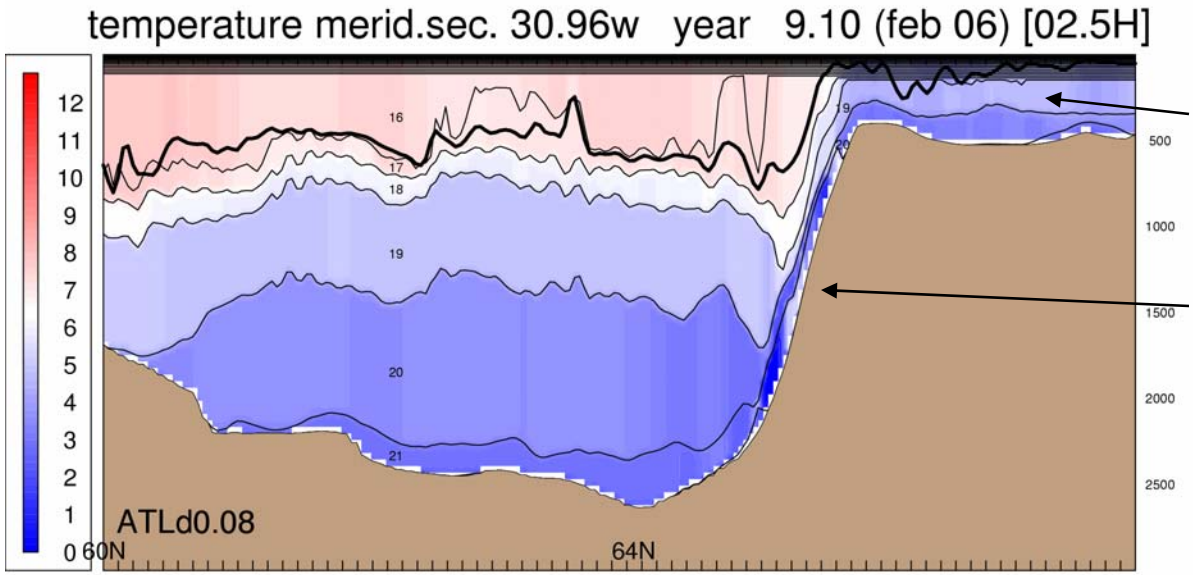
4.14
9.36
13.77



1/12° North Atlantic
HYCOM

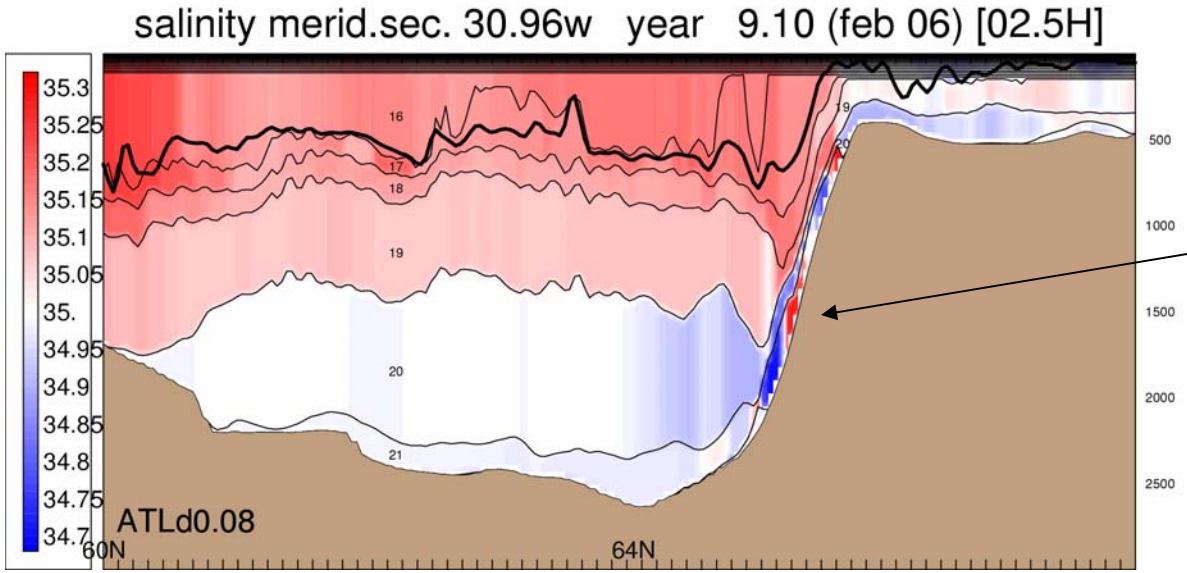
layer 20 mean speed

Denmark Straits Overflow



Cold fresh water forms over shelf In Nordic Seas

and spills over the Denmark Strait



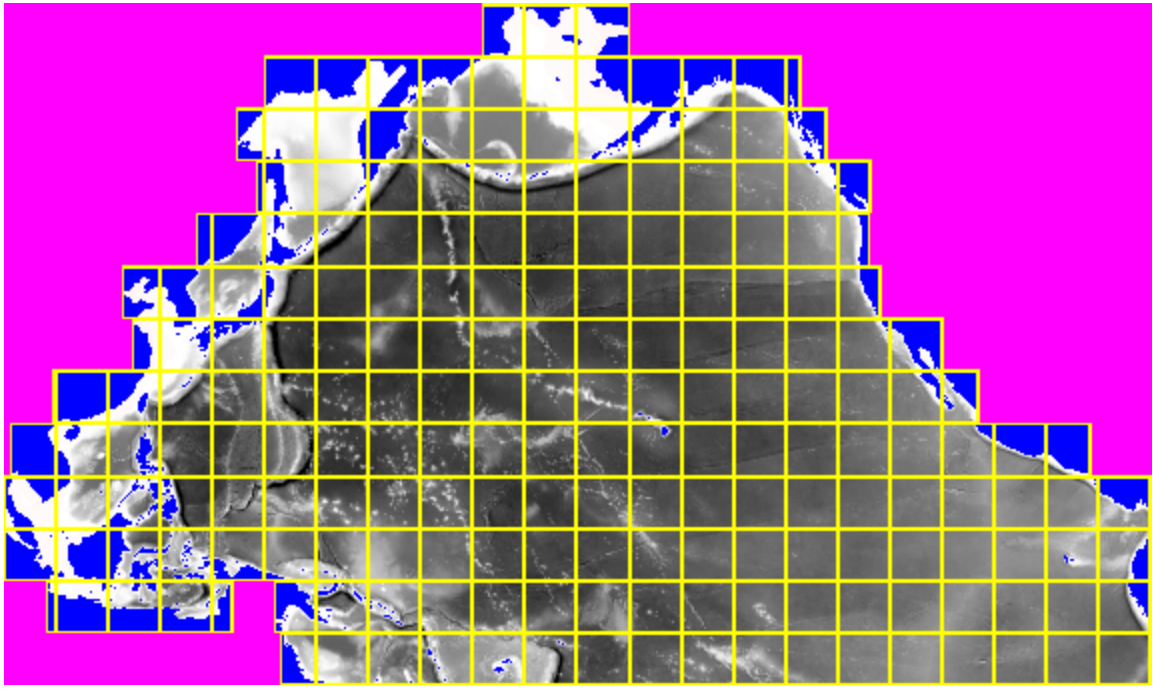
and entrains more saline Labrador Sea water

PACIFIC MODEL CONFIGURATION

- **Horizontal grid: 1/12° (2294 x 1362 grid points, 6.5 km spacing on average)**
- **20°S to 65.8°N**
- **20 vertical coordinates (σ-theta reference)**
- **Bathymetry: Quality controlled ETOP05**
- **Surface forcing:**
  wind stress, wind speed, heat flux (using bulk formula), E-P + relaxation to climatological SSS
- **River runoff**
- **Buffer zone: ~3° band along southern and eastern boundary with relaxation to monthly climatological T and S**
- **Closed boundaries along 20°S, in the Indonesian throughflow region and in the Bering Strait**

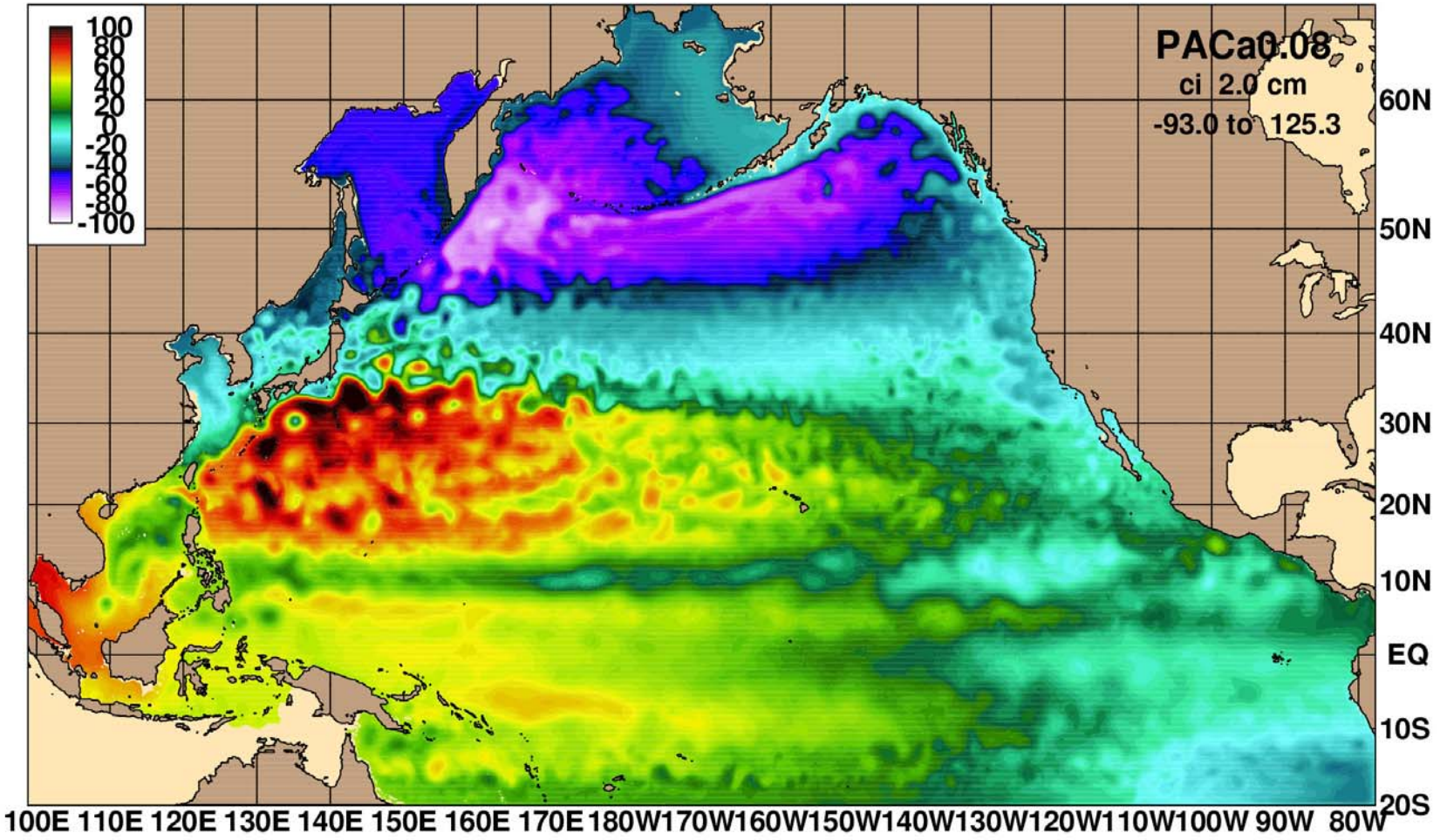
1/12° North Pacific Grand Challenge Project

22 x 13 Equal Area Decomposition (all land tiles discarded)



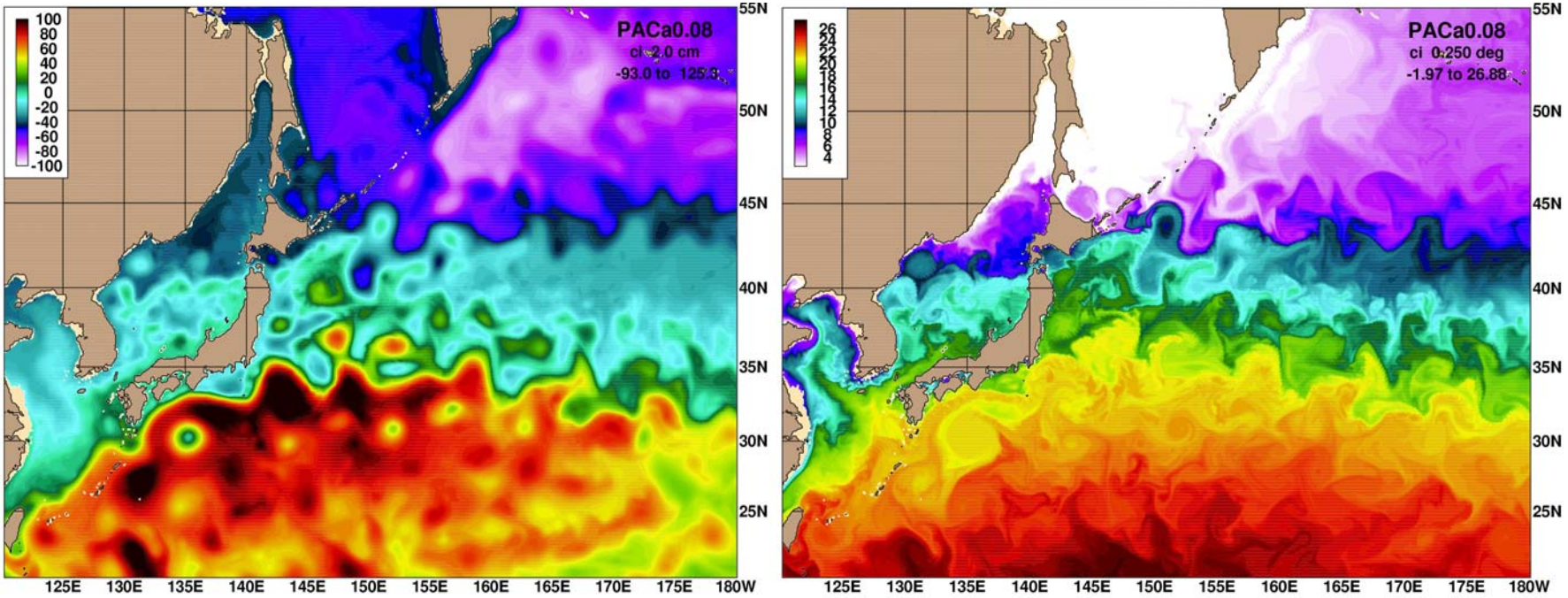
- Running on tempest (MHPCC)
- 51,000 hrs/model year on 207 CPUs
- 325 GB/model year for 3-D fields every 3 days
- MPI parallelization

1/12° Pacific HYCOM
SSH Snapshot – 17 December



Forced with climatological HR winds and ECMWF thermal forcing

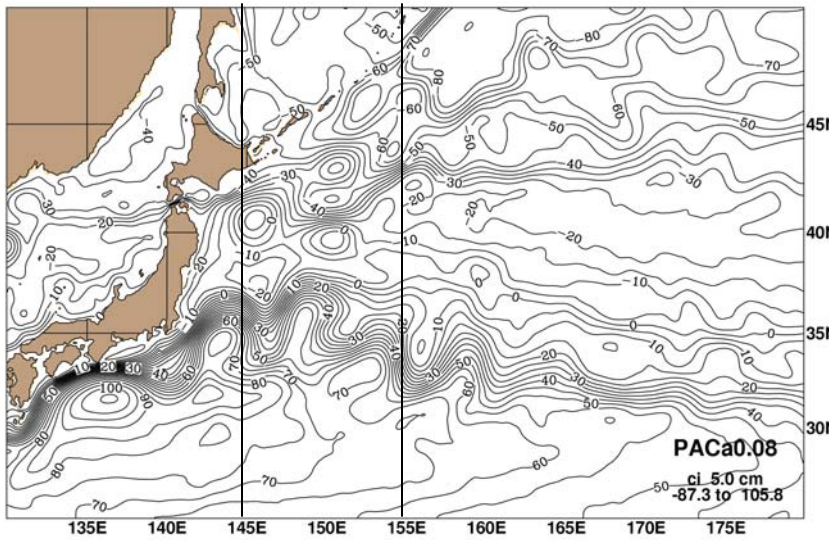
1/12° Pacific HYCOM
SSH and SST Snapshot – 17 December

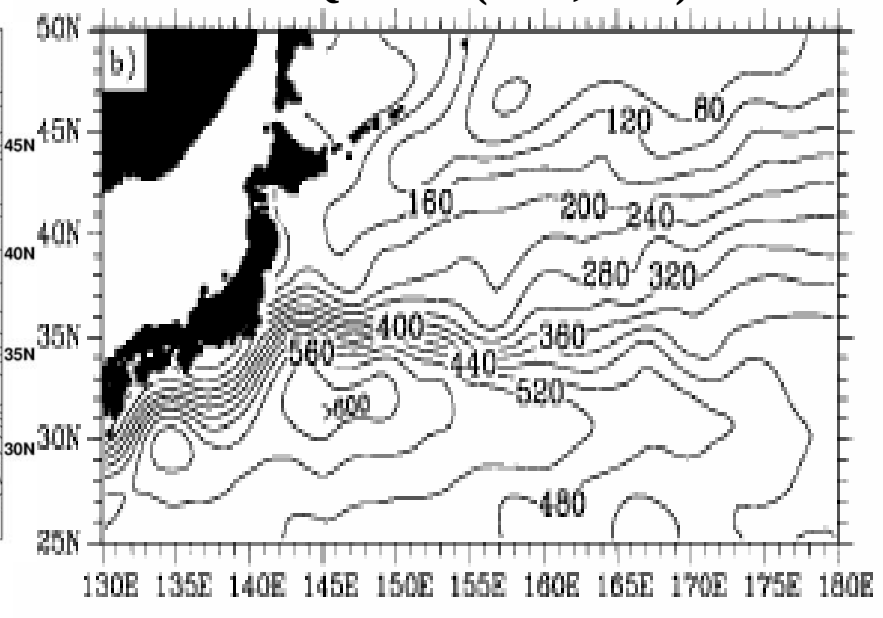


Forced with climatological HR winds and ECMWF thermal forcing

Mean Sea Surface Height
1/12° Pacific HYCOM vs. Observations

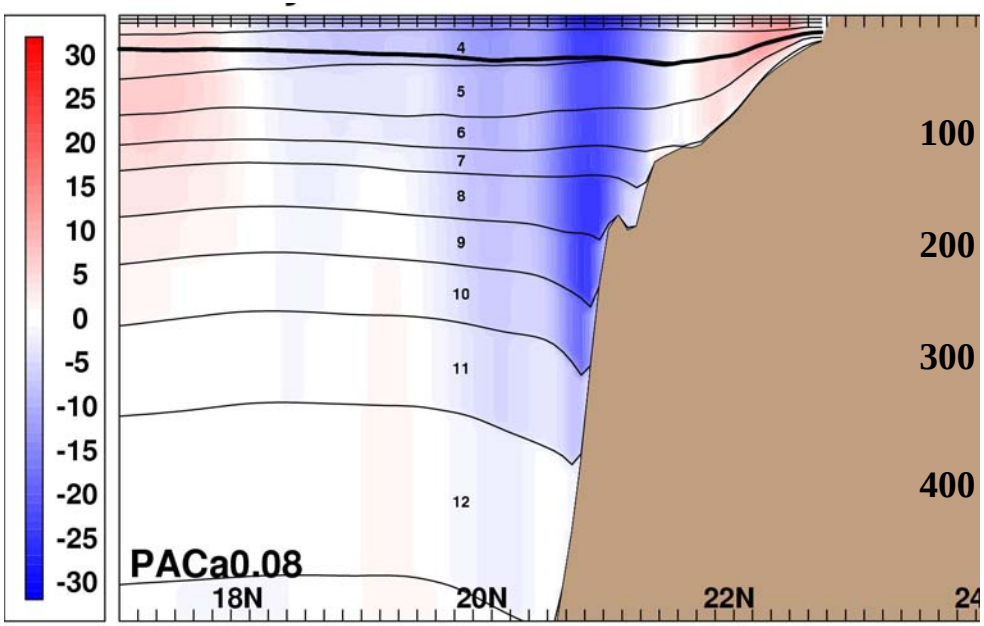
Qu et al. (2001, JPO)



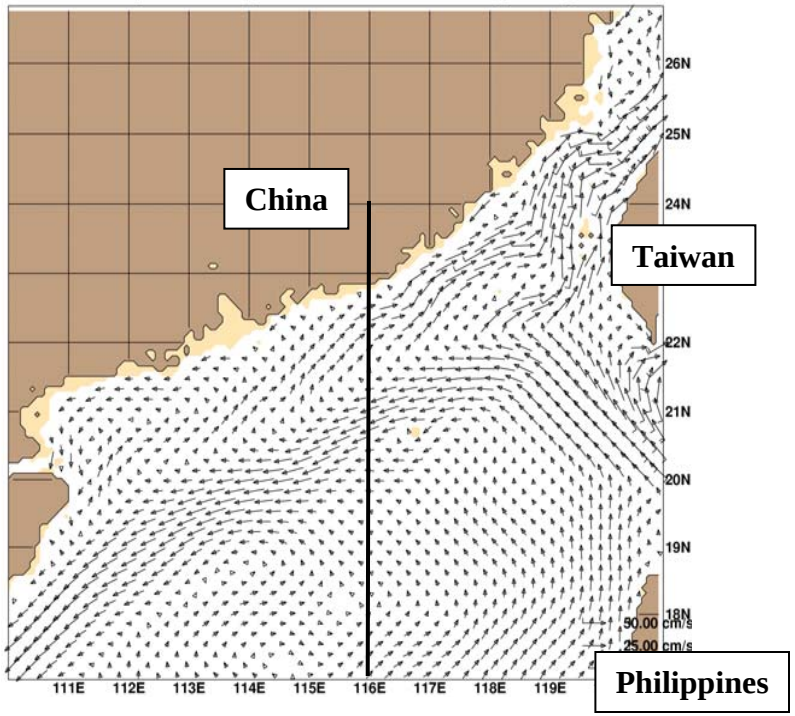


1/12° Pacific HYCOM
Depiction of the South China Sea Warm Current (SCSWC)

Mean zonal currents at 116°E



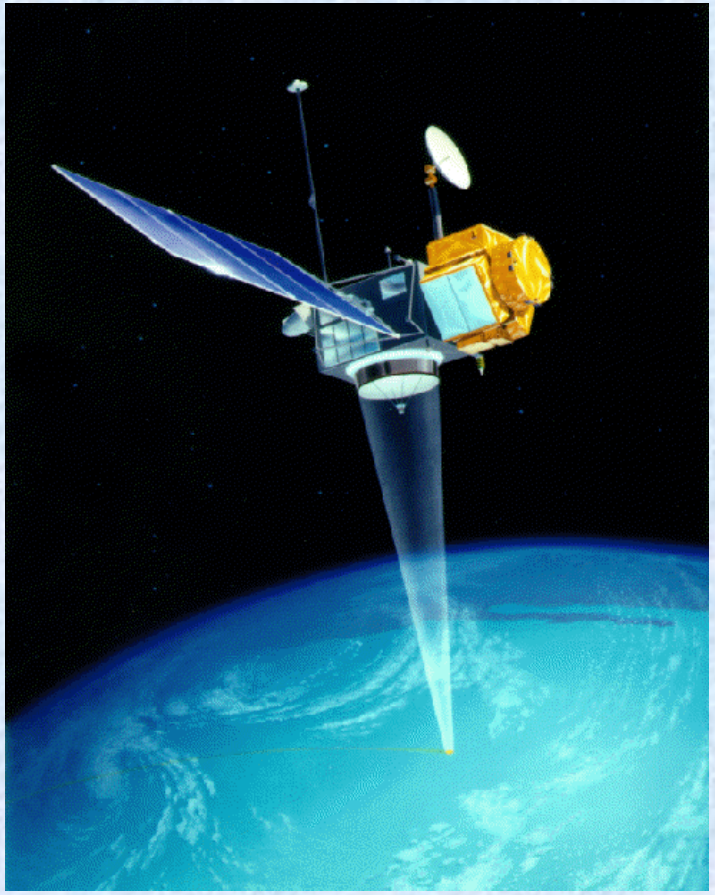
Mean mixed layer currents



SCSWC is a shelf current that flows northeast counter to the prevailing southwestward monsoon winds. Its existence is still somewhat controversial and HYCOM will be a good tool to study the dynamics.

The Data Assimilation Component

- **The main source of data is provided by altimetry**
- **Altimetry gives an estimation of the *surface* circulation**
- **The Adaptive Filter is designed to estimate the *correlation* between *surface* and *sub-surface* circulation**
- **The estimation process requires the adjoint of the model used to perform the forecast**



Present assimilation system

1/3° Atlantic version of HYCOM

Assimilation of the Modular Ocean Data Assimilation System (MODAS) optimal interpolated SSH anomalies from satellite altimetry

Vertical projection of the surface observations by Cooper-Haines

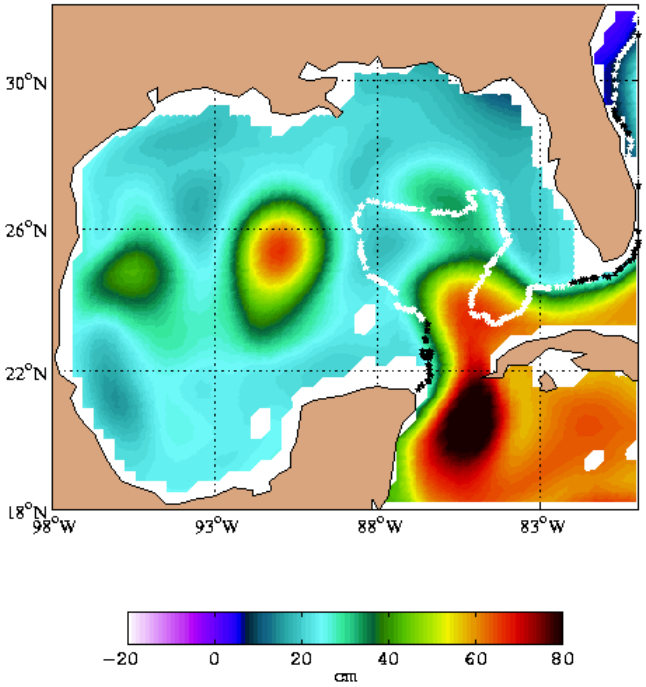
Running in near real-time

Plan to assimilate into 1/12° North Atlantic this FY

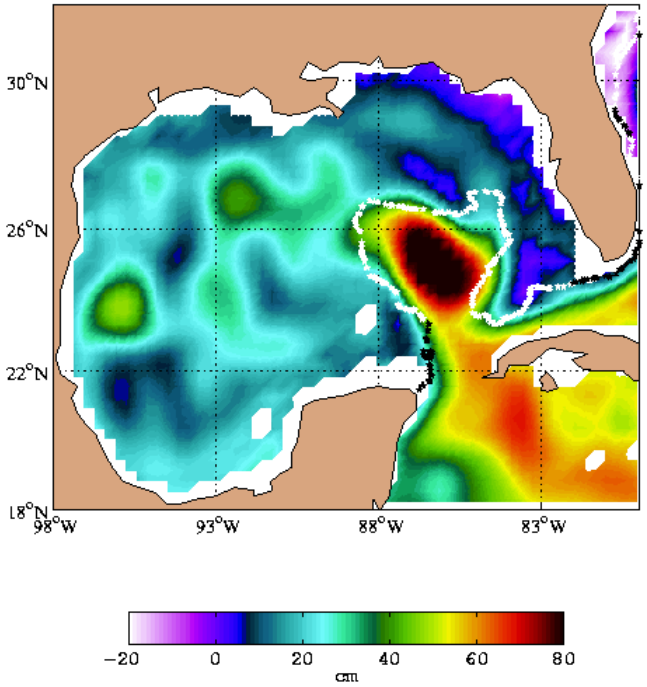
1/3° Atlantic HYCOM SSH

20 November 2000

NO ASSIMILATION



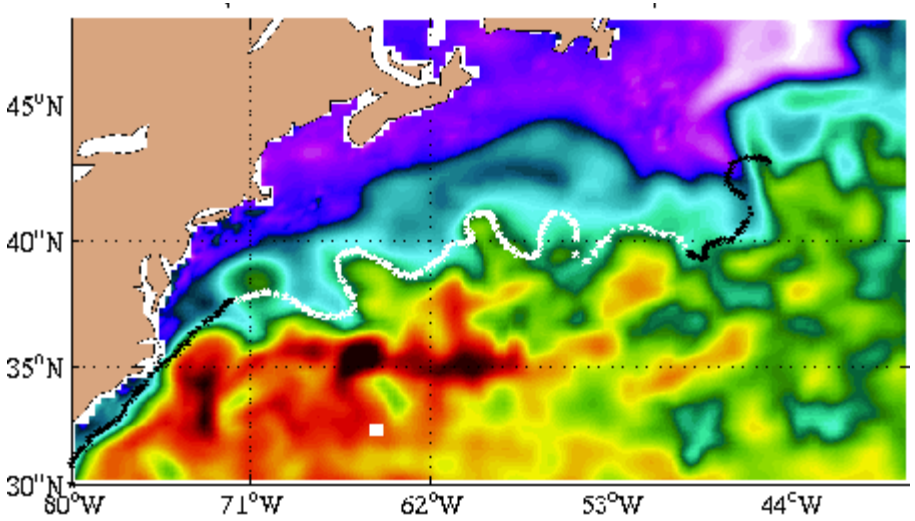
Assimilation of MODAS SSH analyzed fields

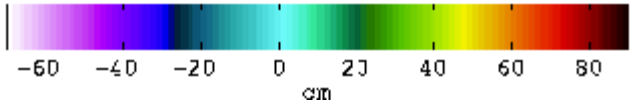


Independent frontal analysis of IR observations performed at the Naval Oceanographic Office overlaid. White line shows the part of the front being observed within the last 4 days. Black line shows the part of the front older than 4 days

1/3° Atlantic HYCOM SSH

30 July 2001





Independent frontal analysis of IR observations performed at the Naval Oceanographic Office overlaid. White line shows the part of the front being observed within the last 4 days. Black line shows the part of the front older than 4 days

Plans for FY03

- Perform 1/12° Atlantic HYCOM nowcasts and a 30-day forecast every week in near real time using existing assimilation scheme
- Test several advanced data assimilation schemes with the 1/12° North Atlantic basin
- Perform additional interannually forced simulations with the 1/12° North Atlantic basin
- Start Interannually forced 1/12° Pacific simulations

WEB PAGE:

http://hycom.rsmas.miami.edu

Coordinator:
Eric P. Chassignet (echassignet@rsmas.miami.edu)